(PATENT)

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	)	
Srinivas BOLLAPRAGADA et al.	)	Group Art Unit 3693
	)	Confirmation No. 4222
Serial No. 10/781,898	)	
	)	Examiner Eric Tak Wai Wong
Filed: February 20, 2004	)	
	)	Attorney Docket 141121-3
	)	

For: SYSTEMS AND METHODS FOR INITIAL SAMPLING IN MULTI-OBJECTIVE PORTFOLIO ANALYSIS

APPEAL BRIEF

MS Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

As required under *37 C.F.R. § 41.37(a)*, this brief is filed within two months of the Notice of Appeal filed in this case on May 8, 2009, and is in furtherance of said Notice of Appeal.

Table of Contents

This Appeal Brief contains items under the following headings as required by 37 C.F.R. § 41.37 and M.P.E.P. § 1205.02:

I. REAL PARTY IN INTEREST

The real party in interest for this Appeal is:

General Electric Company by way of an Assignment recorded at Reel/Frame 014922/0702 on July 28, 2004.

II. RELATED APPEALS AND INTERFERENCES

There are no other appeals, interferences, or judicial proceedings which will directly affect or be directly affected by or have a bearing on the Board's decision in this Appeal.

III. STATUS OF CLAIMS

A. Total Number of Claims in Application

There are 18 Claims pending in application.

B. Current Status of Claims

1. Claims canceled: 4, 14, 20 and 21.
2. Claims withdrawn from consideration but not canceled: None.
3. Claims pending: 1-3, 5-13, 15-19 and 22.
4. Claims allowed: None.
5. Claims rejected: 1-3, 5-13, 15-19 and 22.

C. Claims On Appeal

The Claims on Appeal are Claims 1-3, 5-13, 15-19 and 22.

IV. STATUS OF AMENDMENTS

In the Advisory Action dated January 27, 2009, the Examiner indicates that the Amendment After Final Rejection will be entered for purposes of Appeal. The status of the amendments to the Claims prior to filing the Notice of Appeal is as follows:

A. Responsive to a non-final Office action dated November 9, 2007, Appellant amended Claims 1, 15, 17, 20 and 21, and canceled Claim 14 on February 11, 2008.

B. Responsive to a final Office action dated March 25, 2008 and an Advisory Action dated July 24, 2008, Appellant filed a Request For Continued Examination and amended Claims 1, 17, 20 and 21 on September 5, 2008.

C. Responsive to a non-final Office action dated October 15, 2008, Appellant amended Claims 1, 3, 15, 17 and 18, and canceled Claims 4, 20 and 21 on December 3, 2008.

C. Responsive to a final Office action dated January 22, 2009 and an Advisory Action dated April 7, 2009, Appellant timely filed a Notice of Appeal on May 8, 2009.

V. SUMMARY OF CLAIMED SUBJECT MATTER

Figure 2 shown below provides an overall process chart of the invention, which may be performed by a suitable processing system 1000. As shown in Figure 2, the process starts in step 100 with an initialization of a population of solutions. This might be performed by a population generation portion 102, for example. The initial population is then output to an initial population database 20. After the initial population has been generated, the process of Figure 2 passes to what might be characterized as an efficient frontier generation portion 30, as shown in Figure 2. See *Paragraphs [0088] and [0089].*

The efficient frontier generation portion 30 generates multiple interim efficient frontiers. Specifically, the efficient frontier generation portion 30 includes a number of processing portions (202, 302, 312), as desired, that perform efficient frontier generation processes. The processing portions (202, 302, 312) may perform the efficient frontier generation processes using the same process or different processes. Further details of this processing are described below. As shown, the processing portions (202, 302, 312), as well as the other portions of Figure 2, may be disposed in the processing system 1000. See *Paragraph [0090].*

As a result of the processing of portions (202, 302, 312) multiple interim efficient frontiers (32, 34, 36) are generated. Figure 2 characterizes this processing as performing multiple runs 24. That is, each of the processing of portions (202, 302, 312) perform their own respective run so as to generate the respective efficient frontiers (32, 34, 36). As shown in Figure 2, these interim efficient frontiers are then output to a fusion portion 562. The fusion portion 562 performs a fusion process 560 on the multiple efficient frontiers (32, 34, 36), as described below, so as to generate a fused efficient frontier 560', i.e., an efficient frontier resulting from the fusing operation of step 560. See *Paragraph [0091].*

As shown in Figure 2, multiple runs 22 may be utilized to generate the efficient frontier 36. To explain further, it may be determined through examination of the efficient frontier 36, e.g., as a result of a first run, that the efficient frontier 36 is not sufficient. For example, it might be, that the user senses that the generated efficient frontier 36 is not representative of the global situation. As a result, the process of Figure 2 might be run additional times, i.e., including generation of an initial population 20, generation of the interim efficient frontiers (32, 34, 36), fusing the interim efficient frontiers (32, 34, 36) and further dominance filtering 400' so as to generate a further efficient frontier 36'. Efficient frontiers (36, 36') from multiple runs may then

be combined in some suitable manner, i.e., such as by simply adding the results together, if the user so desires. See *Paragraph [0095]*.

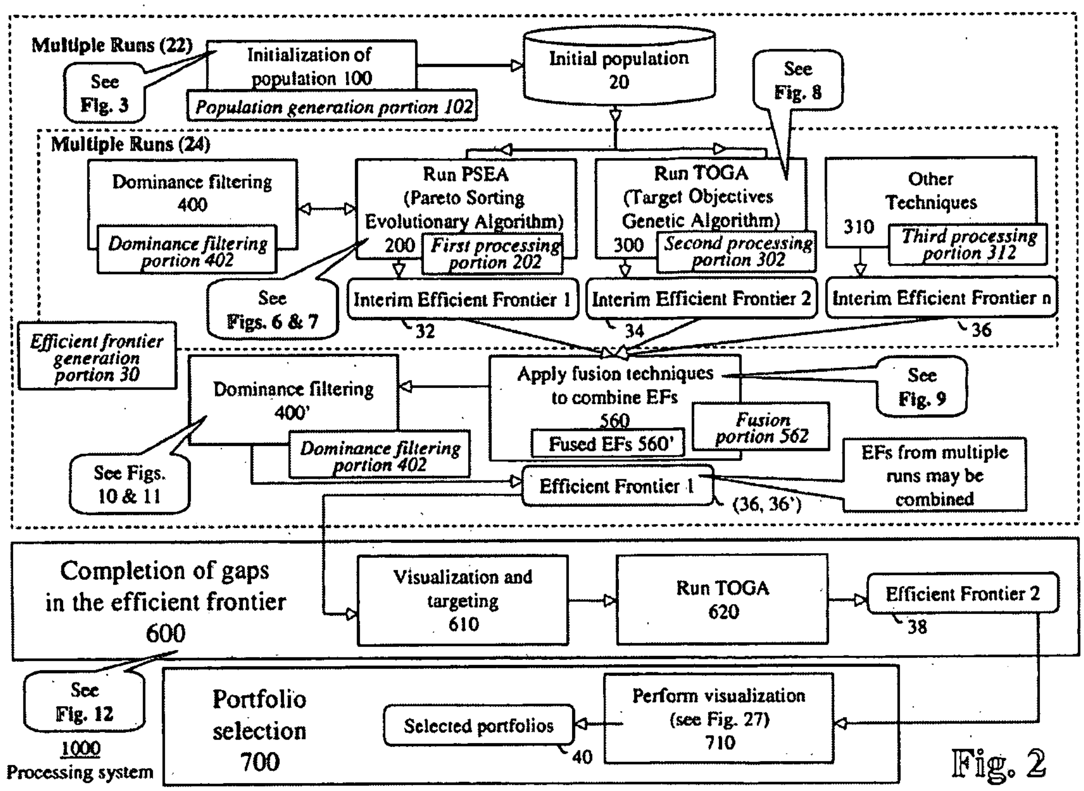


Fig. 2

In accordance with further aspects of the invention, it may be the situation that the measures of return and risk are represented by functions that are arbitrarily non-convex and nonlinear. In this case, there is no computationally tractable algorithmic approach that can guarantee optimality of the identified efficient frontier. In such a situation, a single execution of any of the stochastic multi-objective optimization algorithms described above may be insufficient. However, in accordance with one embodiment of the invention, better coverage of the efficient frontier may be obtained by multiple executions and combination of the results of the executions of a combination of these algorithms. Accordingly, step 560 of Figure 2 shows the application of fusion techniques to combine the interim efficient frontiers to generate the efficient frontier. Further, Figure 9 further shows the fusion processing in accordance with one embodiment of the invention. See *Paragraph [0141]*.

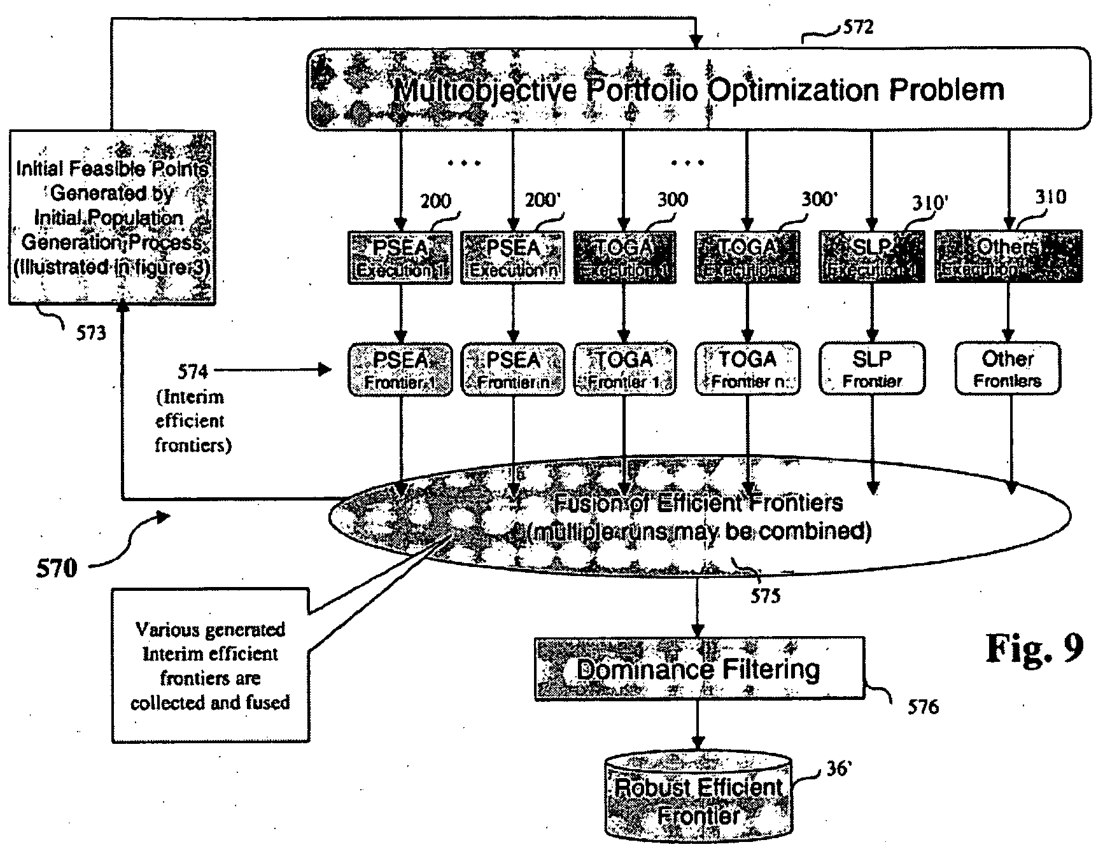


Fig. 9

It is noted that each of the multi-objective optimization algorithms (200, 300, 310) incorporates a different set of stochastic search heuristics. Accordingly, one such algorithm may therefore be better than the other algorithm for certain problems and in certain regions of the efficient frontier. Therefore, an efficient and robust method (for identification of the best possible efficient frontier) is to combine the results of multiple executions of each of these optimization algorithms, and perform a dominance filtering of the fused set of results. This process is described in Figure 9. See *Paragraph [0142].*

That is, Figure 9 shows a fusing process 570 in accordance with one embodiment of the invention. For example, the fusing process might be used in the processing of Figure 2. The application of fusion techniques to combine efficient frontiers starts with a multiobjective portfolio optimization problem, as shown in step 572 of Figure 9. See *Paragraph [0143].*

Once the optimization problem has been prepared as shown in steps 573 and 572, the process passes to steps (200, 300 and/or 310). That is, the process of Figure 9 uses one or more techniques to generate a number of interim efficient frontiers 574. For example, these techniques might include PSEA, TOGA, SLP, and others, for example. Steps (200, 300 and/or 310) might be performed in parallel, for example. See *Paragraph [0144]*.

Once the interim efficient frontiers 574 have been generated, the process passes to step 575. In step 575, the process of Figure 9 fuses the various interim efficient frontiers, which were generated by the processes (200, 300, 310). This fusing is performed by combining the interim efficient frontiers in some suitable manner, as discussed below. Each of the techniques used by the processes (200, 300, 310), shown in Figure 9, may be executed multiple times to yield different efficient frontiers. Various different runs of the techniques may incorporate a different set of stochastic search heuristics, and may respectively focus on particular problems and on particular regions of the efficient frontier. See *Paragraph [0145]*.

Further, it is appreciated that the user might view the generated efficient frontier (from step 575 or step 576) and determine that such generated efficient frontier is not sufficient. For example, the efficient frontier may not have the diversity that the user, e.g., a portfolio manager, desires or expects. Accordingly, the user might rerun the process of Figure 9, so as to attain the desired diversity, for example. The results of the multiple runs might be combined in some suitable manner, as shown in step 578 of Figure 9. See *Paragraph [0146]*.

Further, it is not necessary that each of the techniques be used. For example, only PSEA processing and TOGA processing might be used. Each of the PSEA, TOGA and/or SLP processing feeds into the fused efficient frontiers. That is, in step 575 of Figure 9, the various generated interim efficient frontiers are collected and are fused together. While the fusion technique itself may be based on one of several heuristics, one approach presented herein includes a concatenation, i.e., an augmentation of sets, of the frontiers determined by the various algorithms. However, the fusion processing of step 575 may include other techniques to combine the efficient frontiers 574. Other fusion operators, e.g. probabilistic fusion techniques, may be applied when there exists a measure of uncertainty in the generated efficient frontiers. See *Paragraph [0147]*.

In accordance with one embodiment of the invention, as shown in Figure 9, after step 575 in which the interim efficient frontiers are fused into a single efficient frontier, the single efficient frontier is then passed through dominance filtering. In accordance with one

embodiment of the invention, the novel "fast dominance filtering" as described herein may be used. The dominance filtering is a key step in the fusion of frontiers since this filtering guarantees that only the overall best performing results from each of the algorithm executions are retained. The effect of the filtering is therefore retention of the solutions representing a best, i.e., the best that can be achieved, approximation to the true efficient frontier. This processing results in a robust efficient frontier (36, 36'), as shown in Figure 2 and Figure 9. See *Paragraph [0148]*.

Hereinafter, further aspects of the fusion processing will be described in accordance with some embodiments of the invention. Fusion as described herein may be characterized as relying on two assumptions: (1) the evaluation of a given portfolio is deterministic, i.e., the performance of a portfolio $\overline{X}_i$ (a vector of asset allocations in the portfolio configuration space $\overline{X}$) is represented by a point $\overline{Y}_i = [y_{i,1},...,y_{i,n}]$, defined in an n-dimensional performance space $\overline{Y}$); and (2) each process generating a set of non-dominated points (i.e., any of the execution blocks (200, 200', 300, 300', 310, 310') illustrated in Figure 9) is equally reliable. Under these assumptions the set aggregation, i.e. union, is a reasonable fusion operator. See *Paragraph [0149]*.

It is possible to have situations in which we need to relax one of the above assumptions. In situations when we could no longer assume a deterministic portfolio evaluation, we could face two possible types of evaluation uncertainty: "stochastic' (defined by a continuous probability distribution) and "discrete-probabilistic." Stochastic uncertainty is introduced when the performance of the assets included in a portfolio $\overline{X}_i$ can only be evaluated stochastically. Hence the performance of $\overline{X}_i$ will be a probability distribution defined on each dimension j of the performance space (e.g., return, risk, etc.) Under usual assumptions of normality, this distribution will be represented by a mean $\mu_{i,j}$ and a standard deviation $\sigma_{i,j}$ (average and standard deviation of portfolio $\overline{X}_i$ for performance metric y_j). Therefore, the representation of portfolio $\overline{X}_i$ in the performance space is now $\overline{Y}_i = [(\mu_{i,1},\sigma_{i,1}),...,(\mu_{i,n},\sigma_{i,n})]$. Initially, by using a common statistical transformation we can transform each pair $(\mu_{i,1},\sigma_{i,1})$ into a confidence interval $[a_{i,1},b_{i,1}]$, where $a_{i,1}$ and $b_{i,1}$ are the lower and upper bounds of the confidence interval for a given confidence level α. The representation of a portfolio $\overline{X}_i$ in the performance space is now $\overline{Y}_i = [(a_{i,1},b_{i,1}),...,(a_{i,n},b_{i,n})]$. In contrast with the deterministic evaluation, each portfolio will

now be represented in performance space $\overline{Y}$ by a hyper-rectangle instead of a single point. See *Paragraph [0150]*.

The fusion process will now account for this uncertainty and the set augmentation will be extended to include hyper-rectangles as well as single points. In such a case, it is important to also consider this uncertainty when using the space-decomposition-based dominance filter. Rather than selecting only non-dominated points in the set generated by the fusion, the filter will include a tolerance bound ε, which will retain ε-dominated points. These aspects of the fusion processing in accordance with one embodiment of the invention are described below. See *Paragraph [0151]*.

In Figure 29 we illustrate an example of fusion for the deterministic evaluation of portfolio performance obtained from two sources, A and B. These sources could be any of the execution blocks (200, 200', 300, 300', 310, 310') illustrated in Figure 9. In this example, Source A is generating 3 points, {(1,1), (3,3), (6,5)}, while source B is generating 2 points, {(2,2), (4,4)}. As the points are all distinct, the fusion will generate the union of all five points. See *Paragraph [0152]*.

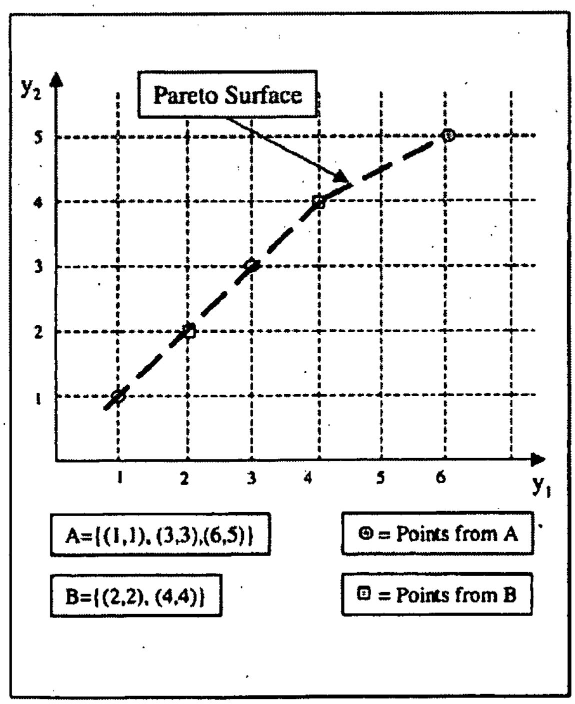
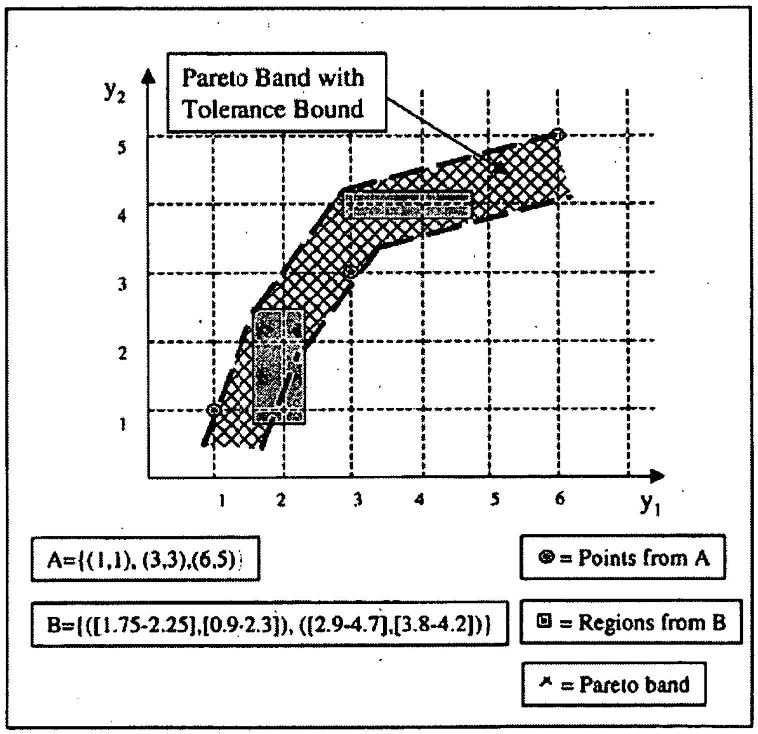


Figure 29

Deterministic Evaluation

In Figure 30, we illustrate the same example but now source B is using a stochastic evaluation of the portfolio performance. In lieu of generating two points, as in Figure 29, after the transformation from the evaluation statistics to the confidence intervals, we now have two regions (defined by rectangles in 2-D spaces and by hyper-rectangles in higher dimensional spaces). The fusion is the union of all regions and points. The same Figure 30 shows a Pareto surface with some tolerance bound, to account for the uncertainty in the evaluation. See *Paragraph [0153]*.

Figure 30



Stochastic Evaluation (Transformed into Confidence Intervals)

A different situation arises when the uncertainty cannot be represented by a continuous probability distribution but rather by discrete probability assignments to subsets of points in the performance space $\overline{Y}$. Imagine for instance that the evaluation of a given metric (e.g., return) can take only one of a small, finite number of values, depending on the outcome of a given event (e.g. the approval of a merger, the granting of a license from a regulatory agency, etc.). See *Paragraph [0154]*.

Instead of creating hyper-rectangles (as we did in the case of stochastic uncertainty), we now have a discrete subset of points, with a probabilistic assignment associated with each singleton point. For example the representation of portfolio $\overline{X}_i$ in the performance space could be described as:

$$\overline{Y}_i = \begin{Bmatrix} \left[\{(y_{i,11}),m_1\}\{(y_{i,12}),m_2\},\{(y_{i,13}),m_3\}\{(y_{i,14}),m_4\},\{(y_{i,15}),(1-m_1-m_2-m_3-m_4)\}\right]\ldots, \\ \left[\{(y_{i,n1}),m_6\},\{(y_{i,n2})(1-m_7)\}\right] \end{Bmatrix}$$

See *Paragraph [0155]*.

This representation can be interpreted as following: in the first assignment, we show that the first metric can take one of five possible values: $y_{i,11}$ through $y_{i,15}$. Each value assignment has an associated probability value. The sum of the probability values for the entire assignment is equal to one. In the last assignment, we show that the last metric can take one of two possible values $y_{i,n1}$ and $y_{i,n2}$. Next to each value we show its associated probability value. See *Paragraph [0156]*.

Note that we could represent the deterministic assignment illustrated in Figures 30 and 31 in this manner, by binding one of the probability values in each assignment (as shown contained in a squared bracket) to one and binding the remaining ones to zero. This concept is illustrated in Figure 31, where the deterministic assignments in source *A* are represented as three probabilistic assignments, each with probability one. That is, Figures 30 and 31 show continuous and discrete probabilistic assignments. See *Paragraph [0157]*.

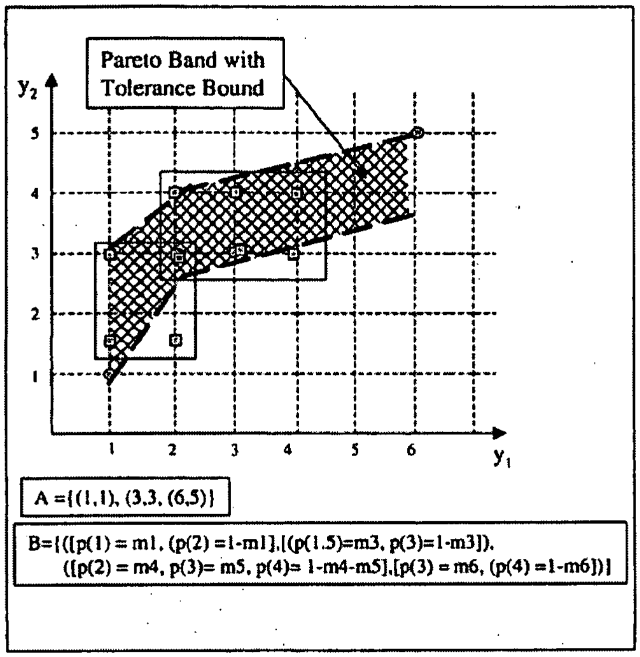


Figure 31

Discrete Probabilistic Evaluation

In the same example in Figure 31, we can observe that source B has generated a "discrete-probabilistic" evaluation. In lieu of the two points or two rectangles we now have two discrete assignments, as indicated in Figure 32. See *Paragraph [0158]*.

After all assignments have been determined, we can perform a "probabilistic fusion," which is derived from an extension of Dempster-Shafer (DS) rule of combination. DS rule has been defined (Shafer, 1967; Dempster, 1976) to implement the "intersection" of the probabilistic outcome of two or more sources. In a generalization of this rule, filed in a previous patent application (U.S. Application Serial No. 10/425,721, filed April 30 2003, which is incorporated herein by reference in its entirety, the inventors redefined DS rule of combination as the "outer product" of two probability distributions using the "scalar product" as an operator. In the same patent application, the inventors generalized DS rule of composition by allowing the outer product operator to be any Triangular T-norms (instead of the scalar product). This is illustrated in the table of Figure 37. See *Paragraph [0159]*.

We recall that Triangular norms (T-norms) and Triangular conorms (T-conorms) are the most general families of binary functions that satisfy the requirements of the intersection and union operators, respectively (Schweizer and Sklar, 1963; Bonissone 1987). T-norms *T(x,y)* and

T-conorms *S(x,y)* are two-place functions that map the unit square into the unit interval, i.e., $T:[0,1]\times[0,1]\to[0,1]$ and $S:[0,1]\times[0,1]\to[0,1]$ They are monotonic, commutative and associative functions. Their corresponding boundary conditions, i.e., the evaluation of the T-norms and T-conorms at the extremes of the [0,1] interval, satisfy the truth tables of the logical AND and OR operators. They are related by the DeMorgan duality, which states that if N(x) is a negation operator, then the T-conorm *S(x,y)* can be defined as *S(x,y) = N(T(N(x), N(y)))*. See *Paragraph [0160]*.

Given that the fusion, in accordance with some embodiments of the invention requires evaluating the "union" of the probabilistic outcome of two or more sources, we extend the previous work set out in U.S. Application Serial No. 10/425,721 (to P. Bonissone, et al. entitled "System And Process For A Fusion Classification For Insurance Underwriting Suitable For Use By An Automated System") by using *Triangular conorms S(x,y,)* as the outer product operators. In Figure 32, we show the results of the fusion using the triangular conorm *S(x,y,)= x+y – x*y*. This conorm is the DeMorgan dual of the scalar product, using the negation operator *N(x) =1-x*. Let's recall that *S(x,y) = N(T(N(x), N(y)))*. Other T-conorms, such as the ones listed in the table of Figure 38, could also be used to account for positive or negative correlation among the sources. See *Paragraph [0161]*.

Figure 32

$$A=\{\ p_1(1,1)=1,\quad p_2(3,3)=1,\quad p_3(6,5)=1\}$$

$$\begin{aligned}B=\{\{\ & p_4(1,1.5)= m1*m3\\ & p_4(1,3)= m1*(1-m3)\\ & p_4(2,1.5)= (1-m1)*m3,\\ & p_4(2,3)= (1-m1)*(1-m3)\},\\ \{ & p_5(2,3)= m4*m6\\ & p_5(3,3)= m5*m6\\ & p_5(4,3)= (1-m4-m5)*m6\\ & p_5(2,4)= m4*(1-m6)\\ & p_5(3,4)= m5*(1-m6)\\ & p_5(4,4)= (1-m4-m5*(1-m6)\}\ \}\end{aligned}$$

Fusion (PF) of multiple assignments to the same point:

$$\begin{aligned}PF(2,3 &= p_4(2,3)+p_5(2,3)-p_4(2,3)*p_5(2,3)\\ &= (1-m1)*(1-m3)+m4*m6-[(1-m1)*(1-m3)*m4*m6\end{aligned}$$

$$\begin{aligned}PF(3,3) &= p_2(3,3)+p_5(3,3)-p_2(3,3)*p_5(3,3)\\ &= 1+m5*m6-1*m5*m6=1\end{aligned}$$

Probabilistic Fusion

Once the fusion is performed, we can use a threshold and only consider those points whose probability is greater than the threshold. This is analogous to the threshold-operation that yielded the confidence interval in the case of stochastic uncertainty. See *Paragraph [0162].*

As a further extension, the probabilistic assignment illustrated in Figure 31 could be extended to "subsets" rather than "singletons," and a similar generalization of the fusion could be applied as well. See *Paragraph [0163].*

Independent Claim 1 specifies, *inter alia*, a method for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the method comprising:

generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

performing <u>a first multi-objective process</u> based on the initial population and the competing objectives <u>to generate a first interim efficient frontier</u> in a portfolio performance space having at least three dimensions;

performing <u>a second multi-objective process</u> based on the initial population and the competing objectives <u>to generate a second interim efficient frontier</u> in the portfolio performance space; and

<u>fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions</u>. (Emphasis added). See *Figures 2, 9 and 29-32; Paragraphs [0088-0091], [0095] and [0140-0163].*

Independent Claim 17 specifies, *inter alia*, a system for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the system comprising:

a population generation portion that generates an initial population of solutions of portfolio allocations, the population generation portion systematically generating the initial population of solutions to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives, the population generation portion including a range value generation portion for varying values of the competing objectives over a range of each competing objective, and a linear program portion for solving a linear program, for each of

the linear constraints, multiple times by setting a weight vector equal to one of the linear constraints and a randomly generated vector;

an efficient frontier generation portion including a first processing portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in the portfolio performance space having at least three dimensions, and a second processing portion for performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions. (Emphasis added). See *Figures 2, 9 and 29-32; Paragraphs [0088-0091], [0095] and [0140-0163].*

Independent Claim 22 specifies, inter alia, a computer readable medium for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the computer readable medium comprising:

a population generation portion for generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

an efficient frontier portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in a portfolio performance space having at least three dimensions, and for performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions. (Emphasis added). See *Figures 2, 9 and 29-32; Paragraphs [0088-0091], [0095] and [0140-0163].*

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

1. Whether Claims 1-3, 5-8, 15, 17-19 and 22 are unpatentable under 35 U.S.C. §103(a) over Zitzler ("Comparison of Multiobjective Evolutionary Algorithms: Empirical Results", hereinafter "Zitzler").

2. Whether Claims 9-13 are unpatentable under 35 U.S.C. §103(a) over Zitzler in view of Hauskrecht ("Linear Program Approximations for Factored Continuous-State Markov Decision Processes", hereinafter "Hauskrecht").

VII. ARGUMENT

1. Rejection of Claims 1-3, 5-13, 15-19 and 22 under 35 U.S.C. §103 over Zitzler

Independent Claim 1 specifies, inter alia, a method for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the method comprising:

generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in a portfolio performance space having at least three dimensions;

performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions. (Emphasis added).

Independent Claim 17 specifies, inter alia, a system for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the system comprising:

a population generation portion that generates an initial population of solutions of portfolio allocations, the population generation portion systematically generating the initial population of solutions to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives, the population generation portion including a range value generation portion for varying values of the competing objectives over a range of each competing objective, and a linear program portion for solving a linear program, for each of the linear constraints, multiple times by setting a weight vector equal to one of the linear constraints and a randomly generated vector;

an efficient frontier generation portion including a first processing portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in the portfolio performance space having at least three dimensions, and a second processing portion for performing a second multi-objective process

based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions. (Emphasis added).

Independent Claim 22 specifies, inter alia, a computer readable medium for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the computer readable medium comprising:

a population generation portion for generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

an efficient frontier portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in a portfolio performance space having at least three dimensions, and for performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions. (Emphasis added).

Zitzler discloses a comparison study of multiobjective evolutionary algorithms. Specifically, Zitzler compares eight algorithms with six test functions. See *Section 6.1*. The outcomes of the first five runs were unified, and then the dominated solutions were removed from the union set for each algorithm and test function. See *Section 6.2* The results were plotted in Figures 1-6.

Appellant agrees with the Examiner that the Zitzler reference does not explicitly teach that the competing objectives and plurality of constraints constitute a portfolio problem, and that the solution space has at least three dimensions. See *Page 3* of the final Office action.

However, Appellant also asserts that Zitzler also fails to teach or suggest another fundamental feature of the claimed invention. The claimed invention is directed to performing a first multi-objective process and a second multi-objective process to generate a first efficient frontier and a second efficient frontier, respectively, and fusing the first and second efficient frontiers to create a fused efficient frontier. See underlined portions of Claims 1, 17 and 22 above.

By contrast, Zitzler teaches unifying a plurality of runs and removing the dominated solutions from the union set for the <u>same</u> multi-objective process in order to compare the eight different multi-objective processes. See *Section 6.2.* In other words, the union set of Zitzler is created from the <u>same</u> multi-objective process, not <u>first and second multi-objective processes</u> as recited in the claimed invention. Thus, there is no mention in Zitzler of performing first and second multi-objective processes to generate first and second efficient frontiers, and then fusing the first and second efficient frontiers to create a fused efficient frontier.

Further, one skilled in the art would not be motivated to modify the Zitzler reference to meet the claimed invention because the Zitzler reference is directed to comparing the efficient frontiers from eight different multi-objective processes. <u>To fuse the first and second efficient frontiers from different multi-objective processes would render the comparison study of Zitzler meaningless</u>.

In view of the foregoing, Appellant asserts that the Examiner fails to establish a *prima facie* case of obviousness, and the rejection of Claims 1-3, 5-13, 15-19 and 22 is unsupported by the art and should be reversed.

In addition, dependent Claim 2 specifies, *inter alia*, that the initial population of solutions is generated by using a combination of linear programming and sequential linear programming algorithms. In no way whatsoever can the Zitzler reference teach or suggest at least this feature.

For at least this additional reason, the Examiner fails to establish a *prima facie* case of obviousness, and the rejection of Claim 2 is unsupported by the art and should be reversed.

2. Rejection of Claims 9-13 under 35 U.S.C. §103 over Zitzler in view of Hauskrecht

Claims 9-13 depend from Claim 1. As stated in VII.1 above, there is no teaching or suggestion in Zitzler of performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier, performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier, and fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier. The Hauskrecht reference adds nothing to overcome this shortcoming in Zitzler.

For at least this reason, the Examiner fails to establish a *prima facie* case of obviousness, and the rejection of Claims 9-13 is unsupported by the art and should be reversed.

In view of the foregoing, Appellant respectfully submits that the application is in condition for allowance. Favorable consideration and prompt allowance of the application is earnestly solicited.

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Respectfully submitted,

By /Peter J. Rashid/

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VIII. CLAIMS APPENDIX

1. A method for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the method comprising:

generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in a portfolio performance space having at least three dimensions;

performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions.

2. The method of claim 1, wherein the generating the initial population of solutions uses a combination of linear programming and sequential linear programming algorithms.

3. The method of claim 1, wherein the competing objectives include risk and return.

5. The method of claim 1, wherein the initial population of solutions includes multiple initial feasible points.

6. The method of claim 5, wherein the multiple initial feasible points are generated by solving linear programs.

7. The method of claim 6, wherein the linear programs utilize randomized parameters.

8. The method of claim 1, wherein the generating the initial population of solutions of portfolio allocations includes generating portfolios with different combinations of risk and returns values.

9. The method of claim 8, wherein the generating portfolios with different combinations of risk and returns values are performed by adding additional risk and return constraints to a linear program corresponding to the risk and return objectives.

10. The method of claim 9, wherein portfolios with substantially all feasible combinations of risk and return values are generated by modifying parameters of the added risk and return constraints.

11. The method of claim 1, wherein the generating the initial population of solutions of portfolio allocations includes generating portfolios with different combinations of competing values.

12. The method of claim 11, wherein the generating portfolios with different combinations of competing values are performed by adding additional competing value constraints to a linear program corresponding to the objectives of the competing values.

13. The method of claim 12, wherein portfolios with substantially all feasible combinations of the competing values are generated by modifying parameters of the added competing value constraints.

15 The method of claim 1, wherein a dominance filter process is applied on the fused efficient frontier to create a global efficient frontier.

16. The method of claim 10, wherein nonlinear risk and return constraints are approximated with linear constraints generated by a sequential linear programming.

17. A system for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the system comprising:

a population generation portion that generates an initial population of solutions of portfolio allocations, the population generation portion systematically generating the initial population of solutions to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives, the population generation portion including a range value generation portion for varying values of the competing objectives over a range of each competing objective, and a linear program portion for solving a linear program, for each of the linear constraints, multiple times by setting a weight vector equal to one of the linear constraintsand a randomly generated vector;

an efficient frontier generation portion including a first processing portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in the portfolio performance space having at least three dimensions, and a second processing portion for performing a second multi-

objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions.

18. The system of claim 17, wherein the competing objectives include risk and return.

19. The system of claim 17, wherein the generating the initial population of solutions of portfolio allocations includes generating portfolios with different combinations of competing objectives.

22. A computer readable medium for multi-objective portfolio optimization for use in investment decisions based on competing objectives and a plurality of constraints constituting a portfolio problem, the computer readable medium comprising:

a population generation portion for generating an initial population of solutions of portfolio allocations in a computing device to substantially cover a portfolio configuration space having a plurality of dimensions defined by the competing objectives and the plurality of constraints;

an efficient frontier portion for performing a first multi-objective process based on the initial population and the competing objectives to generate a first interim efficient frontier in a portfolio performance space having at least three dimensions, and for performing a second multi-objective process based on the initial population and the competing objectives to generate a second interim efficient frontier in the portfolio performance space; and

a fusion portion for fusing the first interim efficient frontier with the second interim efficient frontier to create a fused efficient frontier for use in investment decisions.

IX. EVIDENCE APPENDIX

No evidence pursuant to 37 C.F.R. §§ 1.130, 1.131, or 1.132 is/are entered by the Examiner. Accordingly, no evidence is/are relied upon by the Appellant in this paper.

X. RELATED PROCEEDINGS APPENDIX

No related proceedings pursuant to 37 C.F.R. § 41.37(c)(1)(ii) is/are entered by, relied upon, or submitted by the Appellant with this paper.